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(54) **Stator of electric rotating machine having permanent magnets, and inductor pole designed for this stator**

(57) The stator has, inside a yoke 1, inductor poles 2, each comprising a permanent magnet 5 made from a powder mixed with a bonding agent or compacted. The magnet 5 is formed directly by molding, either on the inside of the yoke 1 or on an intermediate piece fixed in the yoke, parts 6 of the magnet 5 providing its anchorage.

Application: electric rotating machines, in particular electric motors.

"Stator of electric rotating machine having permanent magnets, and inductor pole designed for said stator"

The present invention relates to a stator of an electric rotating machine, such as an electric motor, with inductor poles having permanent magnets arranged inside a yoke.

A stator of an electric rotating machine comprises a yoke made of soft magnetic material, inside which are arranged inductor poles, spaced at regular angular intervals. In the case of a wound stator, the poles are composed of polar masses surrounded by electric windings. If it is a stator having permanent magnets, the poles are composed of permanent magnets to which auxiliary pole pieces optionally are attached.

Traditional permanent magnets, for example made of ferrite, form massive blocks and are generally fixed by cementing to the inside of the yoke. Such a mode of fixation does not readily lend itself to automation.

New magnetic materials have recently appeared, making it possible to make permanent magnets of greater power than magnets made of ferrite, for a smaller volume. Principally these are powder materials, which are mixed with a bonding agent, or which are compacted or agglomerated by another process to form magnets. Materials of this type, such as the powder of a neodymium - iron - boron (Nd - Fe - B) alloy, have already been described in for example an article in the journal Machine Design dated January 9, 1986, pages 24 to 30.

The use of such permanent magnets for making inductor poles of an electric rotating machine proves to be interesting, but it encounters practical difficulties, especially for the fixation of magnets inside the yoke, because of the particular nature of these magnets.

The present invention provides a solution for this problem, by resolving in simple fashion the question of fixation of permanent magnets of the type considered in the yoke, while at the same time optimizing the functioning of the electric rotating machine.

To this end, the object of the invention essentially is a stator of an electric rotating machine in which each inductor pole includes a permanent magnet, made from a powder mixed with a bonding agent or compacted, which is formed directly by molding onto the inside of a part of the yoke or onto an element assembled with the yoke, the molding itself providing fixation of the magnet in this yoke or on the said element.

Thus each permanent magnet may, by a single operation of molding of its constitutive magnetic material, be made in its necessary or optimal shapes, including complex shapes, and be simultaneously fixed by anchoring, either directly in the yoke, or on an intermediate piece designed to be fixed on the yoke.

According to a simple embodiment of the invention, the yoke has apertures arranged at the locations of the inductor poles and each permanent magnet, made from a powder mixed with a bonding agent or compacted, is formed directly by molding in contact with the inner surface of the yoke, with anchoring parts that traverse the apertures of this yoke. Advantageously, the apertures of the yoke are delimited by parts turned toward the inside which have tooth-shaped profiles and which are covered by the anchoring parts of the permanent magnets.

According to another possibility, each permanent magnet, made from a powder mixed with a bonding agent or compacted, is formed by molding onto an intermediate piece made of soft magnetic material, of inwardly-curved profile, having apertures traversed by anchoring parts of the magnet, where the assembly formed by the magnet and by the intermediate piece is fixed in the yoke.

The intermediate piece made of soft magnetic material, making up part of the magnetic circuit of the electric rotating machine and constituting a sort of auxiliary pole piece, advantageously comprises an inwardly-curved principal part inserted between the permanent magnet and the yoke, and prolonged by an inwardly-curved lateral part situated on the side of the magnet, at a distance from the yoke and in the prolongation of the inner surface of the magnet. This latter part is provided on the side of the magnet where the induction reaction creates a field in the same direction as the inductor field, and it provides reinforcement of the total flux that increases with the intensity of the induced current.

Each permanent magnet may be molded on with execution of anchoring parts of the magnet that traverse only the apertures of the associated intermediate piece, which itself is fixed in the yoke by various means. The subassembly formed by the magnet and by the said piece, constituting the inductor pole, may thus be fabricated in advance, to be fixed in the yoke later by for example cementing or welding, or else by mechanical means.

Each permanent magnet may also be molded on with execution of anchoring parts that traverse not only the apertures of the associated intermediate piece, but also the apertures of the yoke that coincide with the previous apertures. In this case, execution of the permanent magnet by molding on simultaneously ensures fixation of the magnet itself

and fixation of the intermediate piece, or auxiliary pole piece, in the yoke.

In the latter case, the inwardly-curved principal part of the intermediate piece, inserted between the permanent magnet and the yoke, may have a width smaller than that of the permanent magnet, on the side opposite the lateral prolongation of this intermediate piece, so that the magnet has a thicker part in contact with the yoke; this part of the magnet, situated in the zone where the induction reaction creates a demagnetizing field, provides better resistance to demagnetization.

Auxiliary pieces made of soft magnetic material, of a variety of shapes and functions, may alternatively be combined with the permanent magnets, these auxiliary pieces being incorporated at the time of the molding operation, which ensures their fixation at the same time as that of the magnets. These may for example be inwardly-curved auxiliary pieces limiting the thickness of the magnets locally. In the case of magnets anchored directly in the yoke, each of these auxiliary pieces is inserted between a portion of the corresponding permanent magnet and the inner surface of the yoke, and comprises apertures that coincide with certain of the apertures of the yoke and that are traversed by certain of the anchoring parts of the magnet. Similarly, in the case of permanent magnets anchored on intermediate pieces as defined above, each of the auxiliary pieces is inserted between a portion of the corresponding permanent magnet and the inner surface of the intermediate piece on which the magnet is anchored, and it comprises apertures that coincide with certain of the apertures of the said intermediate piece and that are traversed by certain of the anchoring parts of the magnet. The addition of such auxiliary pieces made of soft magnetic material limits the volume of the constitutive magnetic material of the permanent

magnets, the cost of which is high, in the zones where these magnets have no tendency to be demagnetized.

Incidentally, in referring to embodiments of stators with permanent magnets anchored on intermediate pieces provided for being fixed on the yoke by various means, the object of the invention, as such, also is an inductor pole having a permanent magnet for a stator of an electric rotating machine, in which the permanent magnet, made from a powder mixed with a bonding agent or compacted, is formed by molding onto a supporting piece of soft magnetic material, of inwardly-curved profile, having apertures traversed by parts of the constitutive magnetic material of the magnet, where the magnet and its supporting piece constitute a subassembly provided for being fixed on a yoke.

In any case, the invention will be better understood with the aid of the description that follows, in reference to the accompanying schematic drawing representing, by way of non-limiting examples, several embodiments of the stator of an electric rotating machine having permanent magnets:

Figure 1 is a cross-sectional view of a stator of an electric rotating machine, executed according to the invention, with magnets formed by molding directly onto the yoke;

Figure 2 is a partial cross-sectional view of a stator of an electric rotating machine, executed according to the invention, with formation of each magnet by molding on of an intermediate piece fixed in the yoke;

Figures 3 and 4 are partial cross-sectional views of stators of electric rotating machines, illustrating respectively variants of the embodiments of Figures 1 and 2, with

auxiliary pieces locally limiting the thickness of the magnets;

Figures 5, 6 and 7 are partial cross-sectional views of stators of electric rotating machines, illustrating other variants of the preceding embodiments.

Figure 1 shows a stator of an electric rotating machine, in particular of an electric motor, with a cylindrical yoke 1 made of soft magnetic material, inside of which are fixed, in the example considered, four permanent-magnet inductor poles 2, spaced apart at regular angular intervals of 90°. Each pole 2 has the general shape of a segment of a cylinder, the angular extension of which is less than 90°.

At the location of each pole 2, the yoke 1 has apertures 3 delimited by parts 4 having tooth-shaped profiles, turned toward the inside, the function of which will appear below.

In the embodiment of Figure 1, each pole 2 is made up solely of a permanent magnet 5. More particularly, the permanent magnets 5 that constitute the four poles 2 are made from a powder, in particular a powder of a neodymium - iron - boron alloy, mixed with a bonding agent and making it possible to obtain by molding magnets of any desired or necessary shape, including complex shapes.

In the example considered, the permanent magnets 5 are made directly by molding on, inside the yoke 1. Each magnet 5 is molded on in direct contact with the inner surface of the yoke 1, and with parts 6 that traverse the apertures 3 of the yoke 1 and which are flush with the outer surface of this yoke. The parts 6 completely enclose the parts 4 in the shape of teeth, and they effect fixation of the permanent magnets 5 by direct anchoring of the magnets on the yoke 1.

Figure 2 shows, partially, a stator of an electric rotating machine with its yoke 1 and one of its inductor poles 2. Each pole 2 is made up of a permanent magnet 5, formed by molding onto an intermediate piece 7, which itself is fixed in the yoke 1.

The intermediate piece 7, made of soft magnetic material, has a profile in the general shape of an arc of a circle and comprises apertures 8 delimited by parts 9 whose profiles have the shape of teeth, turned toward the inside. This piece 7 may be fixed against the inner surface of the yoke 1 by bonding, welding, screwing or riveting.

The permanent magnet 5 is made, as before, from a powder and in particular from a powder of a neodymium - iron - boron alloy, mixed with a bonding agent. In the present case, the permanent magnet 5 is executed by molding onto the intermediate piece 7, in contact with the inner surface of this intermediate piece. At the time of molding, parts 10 of the permanent magnet 5 are formed that traverse the apertures 8 of the intermediate piece 7 and that ensure anchoring of the magnet 5 on this piece 7, by embedding the tooth-shaped parts 9.

Figures 3 and 4 represent, respectively, variants of the embodiments of Figures 1 and 2; the corresponding pieces and parts are designated by the same numerical references, referring to the preceding description.

In these variants, the thickness of the permanent magnets 5 is reduced, in the zones where the magnets 5 have no tendency to be demagnetized, to limit the volume of magnetic material used, the cost of which is high. The volume of magnet eliminated is replaced, on each pole 2, by an auxiliary piece made of soft magnetic material.

In the case of Figure 3, where the permanent magnet 5 is formed by molding on directly in the yoke 1, the auxiliary piece 11 is inserted between a portion of the magnet 5 and the inner surface of the yoke 1. This auxiliary piece 11 comprises apertures 12, which coincide with certain apertures 3 of the yoke 1 and which are traversed by certain of the parts 6 of the permanent magnet 5, providing anchorage of the latter on the yoke 1.

In the case of Figure 4, where the permanent magnet 5 is formed by molding onto an intermediate piece 7 fixed in the yoke 1, the auxiliary piece 13 is inserted between a portion of the magnet 5 and the inner surface of the intermediate piece 7. This auxiliary piece 13 has apertures 14, which coincide with certain apertures 8 of the intermediate piece 7 and which are traversed by certain of the parts 10 of the permanent magnet 5, providing anchorage of the latter on the intermediate piece 7.

Figures 5, 6 and 7 show other variants, in which each pole 2 of the stator comprises, combined with the permanent magnet 5, an auxiliary pole piece 15 made of soft magnetic material. The auxiliary pole piece 15 has a part 15a arranged between the inner surface of the yoke 1 and the outer surface of the magnet 5, and another part 15b situated on the side of the magnet 5. More precisely, the part 15b of the auxiliary pole piece 15 is separated from the yoke 1 and it presents a cylindrical inner surface that prolongs the inner surface of the permanent magnet 5, on the side where the induction reaction creates a field in the same direction as the induction field and provides reinforcement of the total flux, which increases with the intensity of the current induced.

In the case of Figure 5, where the permanent magnet 5 is formed by molding directly onto the yoke 1, the part 15a of the auxiliary pole piece 15 is inserted between the magnet 5 and the inner surface of the yoke 1. This part 15a of the auxiliary pole piece 15, of a width equal to that of the permanent magnet 5, has apertures 16 that coincide with the apertures 3 of the yoke 1 and that are traversed by the parts 6 of the magnet 5, providing anchorage of the latter on the yoke 1.

In the case of Figure 6, the permanent magnet 5 is again executed by molding directly onto the yoke 1, but the part 15a of the auxiliary pole piece 15 has a limited width; thus, this part 15a is present only between a portion of the magnet 5 and the inner surface of the yoke 1. Depending upon its width, the part 15a of the auxiliary pole piece 15 comprises one or more apertures 16, which coincide with one or more apertures 3 of the yoke 1 and which are traversed by the parts 6 of the permanent magnet 5, providing anchorage of the latter on the yoke 1. The permanent magnet 5 retains a greater thickness in its zone, situated beyond the part 15a of the auxiliary pole piece 15, where the induction reaction creates a demagnetizing field, which results in better resistance of the magnet 5 to demagnetization.

In the case of Figure 7, the permanent magnet 5 is formed by being molded onto the part 15a of the auxiliary pole piece 15, itself fixed in the yoke 1 in the same way as the intermediate piece 7 of Figure 2 or of Figure 4.

Here, the part 15a of the auxiliary pole piece 15 has a width corresponding to that of the permanent magnet 5, and it comprises apertures 17 with profiled edges, for anchorage of the magnet 5 on this part 15a by its parts 10.

The embodiments of Figures 2, 4 and 7, with permanent magnets 5 executed by molding onto intermediate pieces 7 or 15, make it possible to form complete poles 2 apart from the yoke 1, then to assemble the poles 2 with the yoke 1; fabrication of the stator may thus be made particularly convenient. The other embodiments (Figures 1, 3, 5 and 6), in which the permanent magnets 5 are made by molding directly onto the yoke 1, are likewise advantageous in that they permit the formation of magnets 5 and fixation of the magnets, as well as any auxiliary pieces, in the yoke 1 in a single operation.

It goes without saying that the invention is not limited only to the embodiments of this stator of an electric rotating machine that have been described above, by way of examples; on the contrary, it embraces all the variants of embodiment and of application based on the same principle. In particular, the scope of the invention would not be exceeded by modifying the material or shape of the permanent magnets, or the arrangement of the auxiliary pieces combined with these magnets, and of course the invention is applicable regardless of the number of stator poles and regardless of the type of electric rotating machine (motive or generative) of which the stator is a part.

CLAIMS

1. Stator of an electric rotating machine, with inductor poles (2) having permanent magnets (5) arranged inside a yoke (1), characterized in that each inductor pole (2) comprises a permanent magnet (5), made from a powder mixed with a bonding agent or compacted, which is formed directly by molding onto the inside of a part of the yoke (1) or onto an element (7) assembled with the yoke (1).

2. Stator of an electric rotating machine according to Claim 1, characterized in that the permanent magnets (5) of its inductor poles (2), formed by being molded on, are magnets made from a powder of a neodymium - iron - boron alloy, mixed with a bonding agent.

3. Stator of an electric rotating machine according to Claim 1 or 2, characterized in that the yoke (1) has apertures (3) arranged at the locations of the inductor poles (2), and in that each permanent magnet (5), made from a powder mixed with a bonding agent or compacted, is formed directly by molding in contact with the inner surface of the yoke (1), with anchoring parts (6) that traverse the apertures (3) of this yoke (1).

4. Stator of an electric rotating machine according to Claim 3, characterized in that the apertures (3) of the yoke (1) are delimited by parts (4) turned toward the inside that have profiles in the form of teeth and that are covered by the anchoring parts (6) of the permanent magnets (5).

5. Stator of an electric rotating machine according to Claim 1 or 2, characterized in that each permanent magnet (5), made from a powder mixed with a bonding agent or compacted, is formed by molding onto an intermediate piece (7; 15) made of soft magnetic material, of inwardly-curved profile, having apertures (8; 16; 17) traversed by anchoring parts (6; 10) of the magnet (5), where the assembly formed by the magnet (5) and by the intermediate piece (7; 15) is fixed in the yoke (1).

6. Stator of an electric rotating machine according to Claim 5, characterized in that the intermediate piece (15) made of soft magnetic material comprises an inwardly-curved principal part (15a) inserted between the permanent magnet (5) and the yoke (1), and prolonged by an inwardly-curved lateral part (15b) situated on the side of the magnet (5), at a distance from the yoke (1) and in the prolongation of the inner surface of the magnet (5).

7. Stator of an electric rotating machine according to Claim 6, characterized in that the inwardly-curved principal part (15a) of the intermediate piece (15) has a width less than that of the permanent magnet (5), on the side opposite the lateral prolongation (15b) of this intermediate piece (15), so that the magnet (5) has a part of greater thickness, in contact with the yoke (1).

8. Stator of an electric rotating machine according to any of Claims 5 to 7, characterized in that each permanent magnet (5) is molded on with execution of anchoring parts (10) of the magnet (5) that traverse only the apertures (8; 17) of the associated intermediate piece (7, 15), which itself is fixed in the yoke (1) by various means.

9. Stator of an electric rotating machine according to any of Claims 5 to 7, characterized in that each permanent magnet (5) is molded on with execution of anchoring parts (6) that traverse not only the apertures (16) of the associated intermediate piece (15), but also apertures (3) of the yoke (1) that coincide with the preceding apertures (16).

10. Stator of an electric rotating machine according to any of Claims 1 to 9, characterized in that auxiliary pieces (11; 13) made of soft magnetic material are combined with the permanent magnets (5), the auxiliary pieces (11; 13) being incorporated during the molding operation, which ensures their fixation at the same time as that of the magnets (5).

11. Stator of an electric rotating machine according to both Claims 3 and 10, characterized in that each one of the auxiliary pieces (11) is inserted between a portion of the corresponding permanent magnet (5) and the inner surface of the yoke (1), and comprises apertures (12) that coincide with certain of the apertures (3) of the yoke (1) and that are traversed by certain of the anchoring parts (6) of the permanent magnet (5).

12. Stator of an electric rotating machine according to both Claims 5 and 10, characterized in that each one of the auxiliary pieces (13) is inserted between a portion of the corresponding permanent magnet (5) and the inner surface of the intermediate piece (7) on which the magnet (5) is anchored, and comprises apertures (14) that coincide with certain of the apertures (8) of the intermediate piece (7) and that are traversed by certain of the anchoring parts (10) of the magnet (5).

13. Inductor pole having a permanent magnet for a stator of an electric rotating machine according to Claim 8, characterized in that the permanent magnet (5), made from a powder mixed with a bonding agent or compacted, is formed by being molded onto a supporting piece (7) made of soft magnetic material, of inwardly-curved profile, having apertures (8) traversed by parts (10) of the material constituting the magnet (5), and the magnet (5) and its supporting piece (7) constituting a subassembly provided for being fixed in a yoke.